

Geochemical sampling of thermal and nonthermal waters in Nevada: Continued evaluation of geothermal resources for electrical power generation and direct-use applications

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Abstract

Nevada has extensive geothermal resources; approximately 239 MW (gross capacity) of geothermally generated electricity are produced annually, and low- to moderate-temperature geothermal fluids are used for space heating and in vegetable dehydration throughout the state. There is great potential for more use of geothermal resources in all the above categories as well as in industrial processing and mineral extraction. There are more than 350 known geothermal systems in Nevada. At least 30% of these do not have modern, complete water analyses, according to data compiled by Garside (1994); many of these have analyses from one spring in a group of springs, but it is not known from which spring in a group the sample was taken, or if it was the highest temperature spring in that group. Additional data are available from a previously digitized database containing all springs and wells on 7.5' quadrangles. From these digitized site locations, there are \approx 1000 springs for which a location is known, but for which there are no available temperature (or chemical) measurements. Although many of these sites are within known geothermal areas and are located near springs for which temperature and/or geochemical data are available, many of these sites are not so located, and require evaluation before the geothermal potential of the area can be assessed. In year 1 of this work (beginning 3/22/02), 78 water samples were collected to begin filling in the gaps in data. Acquiring and evaluating these new data are essential in the first step in determining the geothermal potential of these sites. We propose to continue the sampling of geothermal waters in Nevada to fill in additional data gaps.

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Introduction

There has been considerable research on the geochemical characteristics of various Nevada geothermal resources. Considerable hydrologic and geochemical data are available at numerous sites. However, there are numerous other sites throughout the state that may have potential for utilization of geothermal resources, but for which there is insufficient information publicly available to evaluate the potential of these individual resources.

Figure 1 illustrates the current information available for various thermal springs and wells throughout Nevada. The data used to construct this map were obtained from several sources: Garside and Schilling (1979), Trexler et al. (1983), GEOTHERM, WATSTORE, Southern Methodist University (SMU) web site, Garside (1994), and Shevenell et al. (2000). From this map and the work of Garside (1994), 208 of the depicted springs and 109 of the plotted wells have adequate chemical analyses from which preliminary evaluations of the geothermal resource potential can be made. Most of these sites have generally complete major and trace element analyses available, yet few have any stable isotope information, or chemical data from nearby cold waters from which mixing between deep-seated, high-temperature thermal and shallower nonthermal waters can be evaluated. From the data compiled to construct Figure 1, it was determined that there are 88 areas for which no reliable chemical analyses are available.

Additional springs and wells were digitized from 7.5' topographic maps when their names included "hot" or "warm". These sites are also illustrated on Figure 1 among those that do not have temperature data. From these data, there are ≈1000 hot or warm springs for which there are neither geochemical data, nor even the most basic data of temperature. In FY02, we began filling in these data gaps, collecting and analyzing 78 samples to use in the evaluation of these resources. Sample groups noted in Figure 1 were visited in 2002-3. The number in parentheses indicates the number of samples collected at each group. Preliminary findings have been, and will be, published in the annual GRC transactions: Shevenell et al., 2002; Shevenell and Garside 2003a.

We propose to continue conducting field evaluation and sampling of additional thermal sites in Nevada to determine the geothermal resource potential at these sites. The proposed study will expand and enhance the present knowledge of Nevada's geothermal resources by providing new water chemistry information on less-studied geothermal areas. These data will allow delineation of poorly characterized or understood geothermal areas in Nevada that may be developed for electrical power generation or direct-use applications.

In order to continue filling in gaps in the data on hot and warm springs in the state, additional spring areas that have not been sampled will be visited and documented; their fluids will be sampled for major and trace element chemistry, stable isotopes of water, and noble gas analyses (B. Mack Kennedy, LBNL will conduct the noble gas analyses under separate DOE funding, at no cost to this project). The results of this proposal will assist in exploration and identification of new geothermal resources in Nevada. As such, this proposal addresses the "Resource Assessment" part of this RFP.

In evaluating Nevada Bureau of Mines and Geology Open File Report 94-2 (Garside, 1994) analyses at locations north of 40° latitude, we identified ≈90 areas that should be sampled, excluding the carbonate aquifer terrain of eastern and southeastern Nevada. Many of the unsampled areas are obscure, poorly located, cooler, not flowing, or simply inaccessible. Therefore, not all of these localities will be

sampled. Many of the selected areas are important because they are in the Battle Mountain Heat Flow High and could represent cooled or mixed outflow fluids from a concealed higher temperature resource.

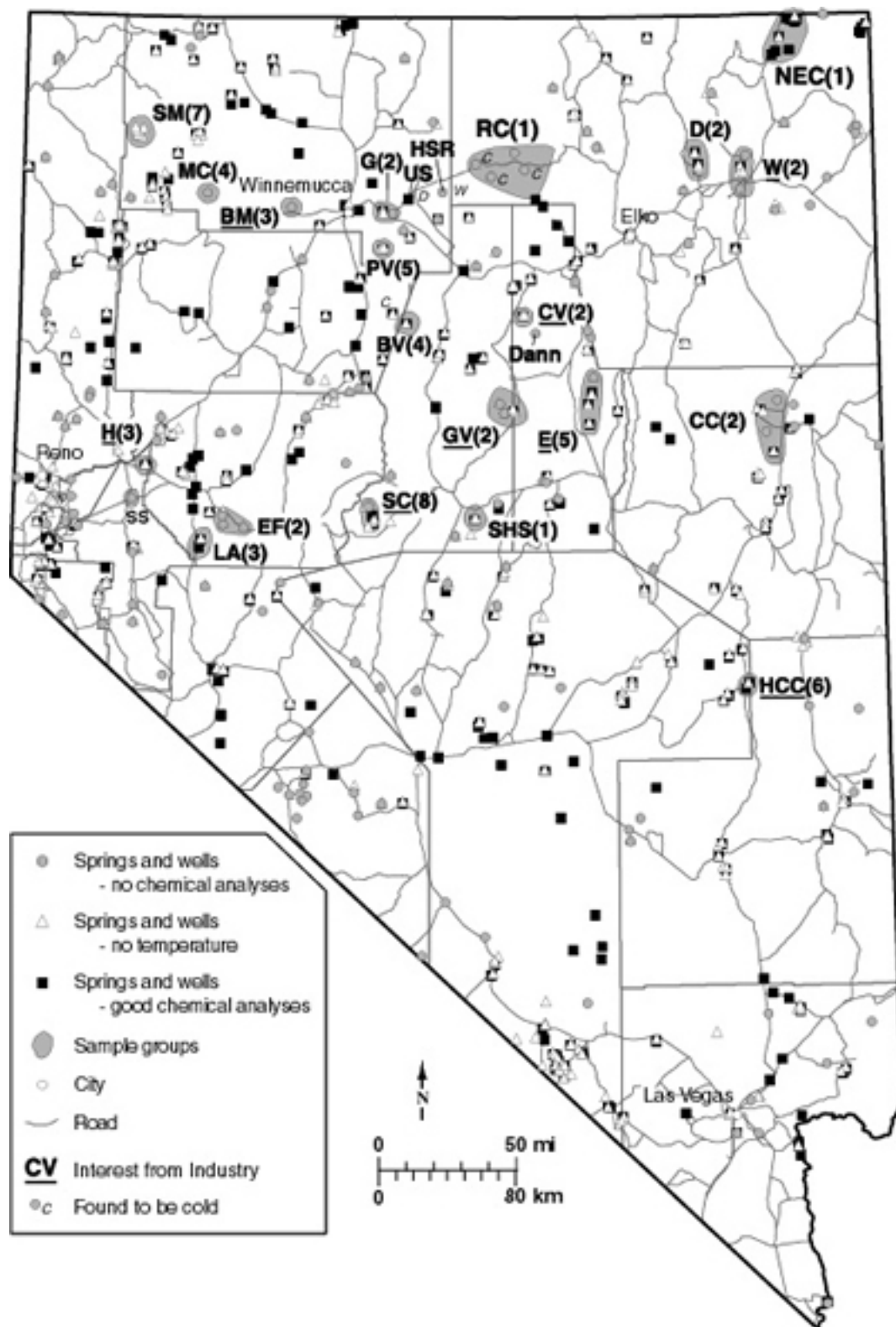


Figure 1. Map of Nevada showing previous and potential future sampling locations.

Some areas that require additional data collection appear on Figure 1 as the shaded circles or open triangles. The ones that were sampled and analyzed in year 1 are noted by the sample groups, identified with an abbreviation followed by the number of samples collected at the site in parentheses. Those areas for which industry has requested data or provided information are identified by the abbreviations that contain an underline.

Typically, ≈ 7 springs will be selected from each area, with five thermal springs (including one from the hottest spring in the group) and two nonthermal springs sampled, depending on availability at the individual sites or regions. Additional water samples may be collected from cold springs in other areas of the state where geochemical data currently are available for nearby hot waters (Garside, 1994).

Approach

Stable isotope, tritium (^3H) and carbon-14 (^{14}C) data have not yet been collected from any of the areas on which we have focused. These data are required to determine the origins and possible ages of the nonthermal fluids for comparison to the thermal fluids to be sampled. This data analysis will help determine the degree and extent to which aquifers may be hydrologically connected, allowing for evaluation of the geothermal component of the fluids.

Data from previous work (Mariner et al., 1975; Garside, 1994) have been used as a starting point, and a newly compiled geochemical database will be consulted in phase 2 of this work to identify areas in need of additional data. Once new sites are selected for sampling, the goals of the proposed work include the same items as the phase 1 work: (1) identifying possible recharge waters/areas of the different geothermal systems; (2) estimating mean residence times of selected fluids; and (3) identifying similarities and differences among the waters to evaluate possible mixing relationships in different areas. These three goals will be accomplished by (1) collection and evaluation of stable isotope data, (2) evaluation of ^3H and ^{14}C data to distinguish fluid ages, and (3) evaluation of major and trace element geochemical data in conjunction with (1) and (2).

Fluid samples will be collected from additional springs throughout the state. Sites will be selected based on the new geochemical database information, and in consultation with stakeholders and industry representatives as was done in year 1. Selected cold springs in the adjacent ranges will be sampled for stable isotopes of water to obtain a better record of variations in these isotopes with elevation.

Major and trace element samples will be filtered through 0.45 μm filter papers to be consistent with previous samplings of other geothermal waters reported (e.g., Garside, 1994). A 100 ml sample for cation analyses (acidified with ultra-pure HNO_3 to $\text{pH} < 2$) and a 250 ml sample for anion analyses will be collected and analyzed at the University of Nevada, Reno, Mackay School of Mines (MSM) analytical laboratories that include Micromass Platform inductively coupled plasma-mass spectrometer with Hexapole collision cell and Merchantek UV laser ablation microprobe. Unfiltered water for δD and $\delta^{18}\text{O}$ (60 ml sample) and ^3H (1 L sample) will be collected. Stable isotopes will be analyzed at the MSM isotope lab, ^3H will be analyzed at the University of Miami, and ^{14}C will be analyzed by Betadyne. Due to the high cost of ^3H and ^{14}C analyses, only a subset of the springs will be selected for analysis, distributed among the areas selected. For ^{34}S and ^{13}C , two 250 ml polypropylene bottles are used. Slightly less than 250 ml of filtered (1.6 μm) water is added to each bottle, and 5 to 10 ml of BaCl_2 solution then added to each. To the ^{13}C bottle 5 ml of 1% NaOH supplied in a glass vial will also be added. Both will be analyzed at the MSM isotope laboratory. To the 1 L filtered ^{14}C sample, 10 ml of BaCl_2 solution and one vial of 4% NaOH are added.

These samples will be collected in collaboration with B. Mack Kennedy (LBNL) who is currently funded to sample and analyze geothermal waters in Nevada for noble gases and selected isotopes. All sampling and analyses will be coordinated through Kennedy in order to maximize the benefits of each sampling and evaluation program and avoid duplication of efforts.

Results

The study is expanding and enhancing the present knowledge of Nevada's geothermal resources by providing new water chemistry information on known geothermal areas for which there is currently little or no information that is publicly available. These data will provide clearer indications of the potential of new or poorly understood geothermal areas in Nevada that may be developed for electrical power generation or direct use applications. Geochemical indicators of fluid flow paths and results from the ^{13}C , $\delta^{18}\text{O}$, δD and ^{34}S will all be used as natural tracers in the individual groundwaters. With the results of this work, we can begin to identify distinct and different origins and evolutions of the various waters when used in conjunction with the evaluation of the inorganic chemical variations in the systems. From the $\delta^{18}\text{O}$, δD and radiogenic isotope results, an initial assessment of the timing and location of recharge to selected aquifer systems will be gleaned, which provide useful information for developing conceptual models of the individual systems.

The newly acquired geochemical data will be used in conjunction with the currently available geochemical data (e.g., Garside, 1994) to evaluate geothermal resources at selected sites throughout the state of Nevada. A suite of geothermometers will be computed and evaluated for the new sites sampled. In conjunction with estimated geothermometer temperatures, possible mixing relationships will be computed using stable isotope data and selected major and trace element data (e.g., B., Cl, Li, Br) for each site or region to provide a preliminary assessment of likely reservoir temperatures from which the mixed spring waters originated. The results of the geochemical analysis and evaluation will be used to assess the hydrologic relationships between the thermal and the nonthermal waters. Relationships relative to fault locations will be illustrated on maps constructed with the use of GIS techniques.

Simple computations will be used to estimate possible depths to the reservoirs using information such as known heat flow, thermal gradients (SMU, 2000), boiling point to depth curves, and an empirical trend identified for Nevada (Flynn and Schochet, 2001). The results of the proposed work will expand our current knowledge of the distribution and characteristics of geothermal resources in Nevada. Present knowledge of resource potential in Nevada will be enhanced by providing an evaluation of selected known resources in the state, and noting likely temperature and depth of the resource, and whether the resource might be used for electrical power generation or direct use applications. Trace elements deleterious to aquaculture will also be analyzed and reported. The results of the proposed work will be publicly available and can be used by others to move to the next step in the exploration process to verify the resource.

As a result of the first year of this project, this new data (and data being compiled under a separate project) were requested by and shared with numerous individuals. We also shared data with Julia Watkins (Geothermal Energy Association) in her work to create a nationwide database of geothermal features. Data were provided to Jim Lovekin (GeothermEx) to support his assessment of geothermal resources in western Nevada. We held meetings and shared newly collected data with numerous individuals who became aware of our project: Tom Evans (Independent; Smith Creek), Rick Selling (Advanced Thermal Systems; Smith Creek), Dick Benoit (Independent; Hot Creek Canyon; Dixie Valley), Andy Ryder (Fairbank Engineering; Crescent Valley), Skip Matlick (Ormat; Grass Valley and Smith Creek), Brian Fairbank (Fairbank Engineering; Blue Mountain), Sam Bell (RTW Engineering; Wells), Roger Johnson (Independent; Pumpernickel Valley), Jim Kingzett (Geothermal Rail Industrial Development; Hazen), Jon Hutchings (Eureka County Natural Resources, sites in the county). Some of these individuals actively participated in the project by collecting samples (Dick Benoit, Hot Creek Canyon) and submitting them to us; by visiting a site and providing detailed notes (Andy Ryder, Crescent Valley, Dann hot springs); by accompanying us during sampling (Jon Hutchings, Eureka County); and, by providing samples from a new corehole (Brian Fairbank, Blue Mountain). Because this project has

enjoyed such support and interest from advocates for geothermal development, we believe this project should be continued in subsequent years.

Also as a result of work done in year 1, we visited sites that were proven not to be thermal, although they had been located previously on geothermal resources maps of Nevada. These sites are now removed from the Nevada locations database, and a new resource map (NBMG Map 141; Shevenell and Garside, 2003b) has been published.

Deliverables

Principal investigators will present results at professional conferences, including the 2003 Geothermal Resources Council annual meeting where continuing results of the sampling campaign will be presented. At least one journal article will be published in a refereed journal such as *Geothermics* or *Journal of Volcanology and Geothermal Research*. There will be no restrictions on the distribution and use of the acquired data and associated evaluation of the geothermal potential of the sites throughout Nevada. All data will be publicly available for free on an NBMG web page, and individual operators in Nevada will be notified of the existence of the data. Data have been provided continuously to industry in the course of this project.

Milestones

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| 1. Present Year 1.5 summary at annual Geothermal Resources Council meeting | Oct 2003 |
| 2. Complete Phase 2 spring sampling | May 2004 |
| 3. Complete Phase 2 water analyses | Aug 2004 |
| 4. Complete geothermometer and mixing calculations | Dec 2004 |
| 5. Complete final report evaluating geothermal potential of sampled sites | May 2005 |
| 6. Provide data and preliminary results to industry and other stakeholders | ongoing |

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